Developing High Altitude Balloon Curriculum for Undergraduate Courses – NSF Grant Impact and Example in General Education Chemistry

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The High Altitude Research Platform (HARP) at Taylor University is a high altitude balloon system with unique telemetry capability to measure altitude, temperature, pressure, humidity, visible light intensity, ultraviolet, infrared, acceleration (accelerometer), radiation (Geiger Counter) while continuously streaming data back to earth in real time. Over 30 universities are implementing HARP into science and engineering courses with statistically significant increases in student intrinsic motivation, valuing science, application knowledge, metacognitive processes, cognitive skills, and content knowledge. Additional results from student learning assessments show that the desired gains typically do not come until multiple implementations into the same course takes place. This, in addition to a survey showing 92% of faculty interested in developing HARP curricula, shows that there is a high need for the development of curricula for the implementation of HARP. A current National Science Foundation (NSF) grant is focusing on meeting this need. In addition, the development of HARP curriculum for the general education chemistry course at Taylor University over 5 semesters resulted in statistically significant increases in five of the six learning areas and practically significant increases in four of those learning areas.

Nomenclature

p	=	statistical probability that the pre-test and post-test results are the same
cta^2	=	ratio of variance from an analysis of variance (ANOVA)

I. Introduction

Taylor University's High Altitude Research Platform (HARP) was initiated in 2003 by Dr. Henry Voss and Mr. Jeff Dailey undergraduate science and engineering classrooms. Of those, over 30 universities implemented HARP into their curriculum.to test sensors and instruments that are launched into space to gather data on space science. Undergraduate students were involved with this work and it soon became evident that HARP made learning fun and exciting. HARP is a typical weather balloon that goes up to near space 100,000 feet (20 miles) above the earth before bursting and descending back to the earth. What differentiates HARP from other weather balloons is its telemetry capabilities including sensors which measure altitude, temperature, pressure, humidity, visible light intensity, ultraviolet, infrared, acceleration (accelerometer), and radiation (Geiger Counter) while continuously streaming data back to earth in real time. In addition, high definition video and still cameras can take pictures throughout the balloon flight. Using GPS, the balloon can be tracked at all times and ultimately recovered.

Since 2003, Taylor University has continued to develop and refine HARP and implement it in Taylor undergraduate classes such as astronomy, chemistry, and engineering courses and capstones. Since 2007 Taylor University has received two grants (Grant No. 1047557 and Grant No. 0717787) from the National Science Foundation (NSF) and has trained 59 faculty and staff from 51 universities on how to implement HARP into their undergraduate classrooms. Of those, over 30 universities implemented HARP into their curriculum.

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In addition, quantitative assessment of student learning as a result of using HARP in undergraduate science and engineering curriculum has taken place in many classes in these universities. Learning in the following areas was assessed: intrinsic motivation, valuing science, application knowledge, metacognitive processes, cognitive skills, and content knowledge. The key instrument was a self-assessment survey given to the students before (pretest) and after (posttest) using HARP in the classroom. This instrument was shown to have excellent reliability with a pre-test Cronbach's alpha of 0.976 and the post-test Cronbach's alpha of 0.965. The instrument was also proved to be valid by using several methods such as statistically showing that students with more science and engineering training score much higher than those with less training and showing consistent growth in students from pre-test to post-test (known group difference method).[1]

As a result of this quantitative testing, use of HARP in undergraduate classes was shown to give statistically significant gains in all learning areas and practically significant gains in many of these areas. Longitudinal studies also showed that as HARP was implemented in the same course repeatedly, the gains in the learning areas increased. This showed that refinement of implementing HARP in a particular course over time resulted in more statistically and practically significant gains in student learning.

This refinement of HARP implementation over time supports that development of proven curriculum using HARP is needed to realize the gains in student learning that are desired. In addition, a survey of faculty implementing HARP showed that 92% of those responding were "interested" or "very interested" in the development of curriculum using HARP. Therefore, the development of curriculum is critical for the use of HARP in undergraduate science and engineering courses.

II. Development of Curriculum Under NSF CCLI/TUES Grant

As a result of this critical need for curricula, Taylor University proposed and was awarded a NSF grant (Grant No. 1047557) under the Course, Curriculum, and Laboratory Improvement (CCLI) program that is now the Transforming Undergraduate Education in Science, Technology, Engineering, and Mathematics (TUES) program. This grant includes funding to develop several different types of curricula that will be available to faculty at all universities.

The curricula that will be developed will have the potential for 1) use at many universities across the U.S. and/or 2) use in multiple courses. In order to be used at many universities, it should be used in courses that are commonly offered and most likely foundational for many degrees. Examples include general chemistry, introductory physics, engineering and computer science courses required for multiple engineering disciplines, calculus, etc. The development of modules that teach specific scientific and engineering principles that can be incorporated in many courses would also be desirable.

The NSF grant allows faculty to receive stipends and funds for supplies in order to develop curricula. Key requirements for a particular curriculum being developed includes:

1. Clear and specific learning objectives
2. Detailed information on experiments including specific procedures, list and description of equipment, etc.
3. Detailed description of data analysis procedures
4. Detailed description of what students need to have mastered before performing the HARP experiment
5. Assessment of achievement of learning objectives after testing curriculum in a classroom.

III. HARP Implementation in General Education Chemistry Course

HARP was implemented into the CHE 100 – Chemistry for Living course at Taylor University which is a general education course for non-science majors. HARP was used 5 different times in this course over 5 different semesters with different students in the course each time. Continuous changes were made to how HARP was implemented in the course based on feedback from the quantitative assessment of student learning.

Hands-on learning of the Scientific Method was central to the implementation of HARP each semester (Fig. 1). In addition, critical thinking skills were emphasized increasingly each semester. The critical thinking skill of prediction was emphasized during the hypothesis formulation and experimental design stages. The critical thinking skill of problem solving was emphasized during the experiment refinement stage to anticipate problems ahead of time and implement solutions. The critical thinking skill of analysis was used during the analysis of the data after the experiment was performed. The metacognitive processes of planning, monitoring, and assessing were implemented at the beginning, middle, and end of the project.

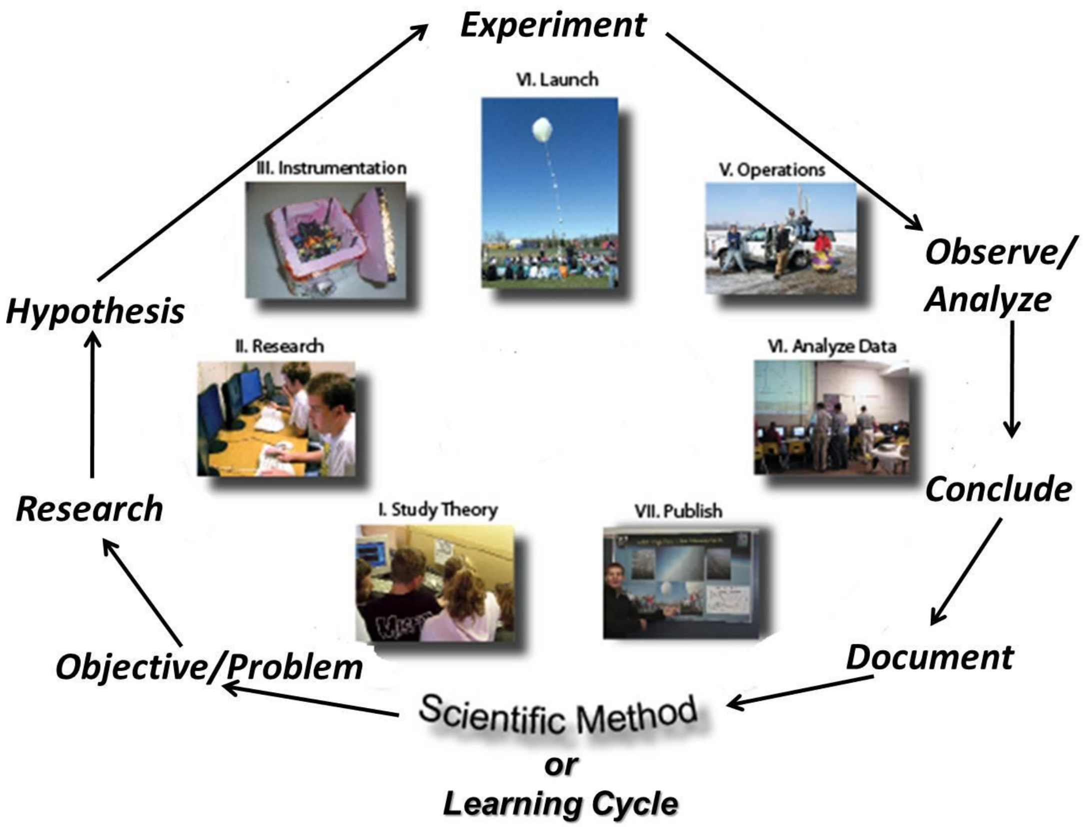

Figure 1. Scientific Method Cycle

Typically, students worked in groups of 4-5. Each group was responsible for coming up with an objective/problem in an area of chemistry given to them. The group then needed to look into the existing literature (research) typically through internet searches. They then gave came up with a hypothesis and designed an experiment using HARP. A HARP launch then took place to perform their experiment. The resulting data were then analyzed and a conclusion was reached with respect to their hypothesis. The overall scientific method was documented in poster, and/or written report, and/or presentation format.

Three 2 hour lab periods were used to do the project with the balloon launch between the second and third lab. The first lab was used for the group to come to consensus on an objective/problem and hypothesis in addition to designing the experiment. The second lab was used to build/refine the experiment, do trial testing, calibrate the sensors, and perform control experiments as needed. The third lab was used to analyze the results including heavy use of Excel to analyze the sensor data and run other analytical tests on objects that were sent up with the balloon. A 1 hour class time was used for final presentations.

Results from the quantitative assessment of student learning as described in the introduction were obtained after the fourth implementation of HARP into CHE 100. Figure 2 shows the results from the self-assessment pre-tests and post-tests. Note that p is the statistical probability that the pre-test and post-test results are the same. (e.g. $p = 0.01$ means that there is 1% probability that the pre-test and post-test results are the same.) Therefore, the smaller p is means that there is a statistical difference between the pre-test and post-test. Table 1 shows the statistical significance of the subareas under each of the six learning areas.

Note that five of the six learning areas show statistically significant increase as a result of implementation of HARP into the course. The following areas also showed practical significance (meaning that the increases are large enough to not only be statistically different but large enough to be of practical value): Intrinsic Motivation ($cta^2 = 0.28$), Application Knowledge ($cta^2 = 0.46$), Metacognitive Processes ($cta^2 = 0.35$), and Content Knowledge ($cta^2 = 0.35$).

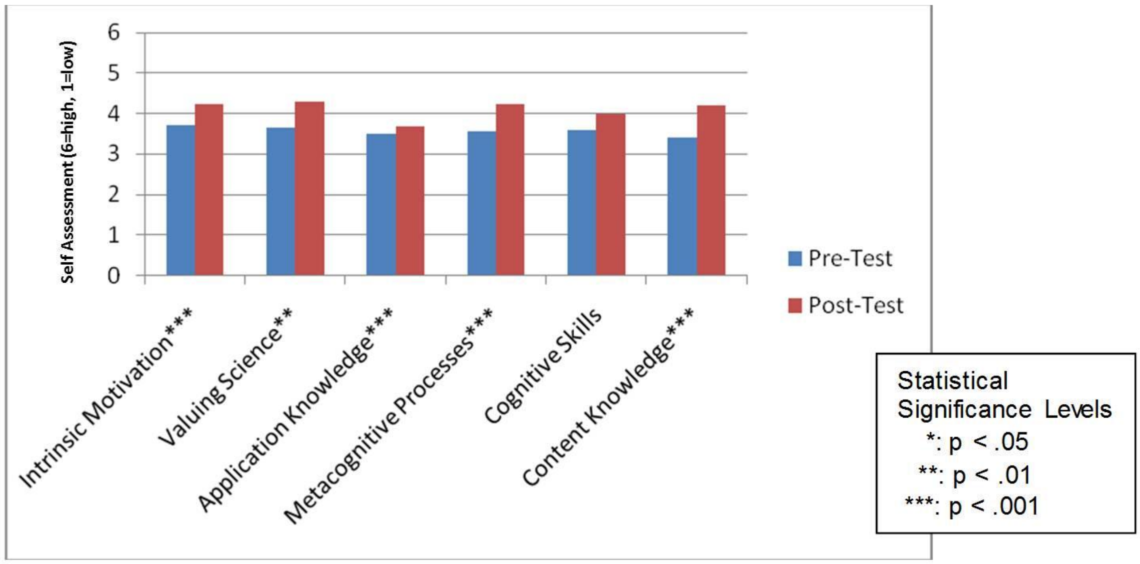

Figure 2. Comparison of Pre-test and Post-test Results

Table 1. Statistical Significance of Sub Learning Areas

Variable
1. Intrinsic Motivation
a. Contextualization
b. Curiosity
c. Challenge
d. Control
e. Cooperation
2. Valuing Science
3. Application Knowledge
a. Apply Problem Solving
b. Process of Evaluation
c. Documentation and Reports
4. Metacognitive Processes
a. Metacognitive Planning
b. Metacognitive Assessing
c. Metacognitive Monitoring
5. Cognitive Skills
6. Content Knowledge
a.a. Primary Technical Knowledge
b. Scientific Method Knowledge

Table 1. Significance Levels
Red: $p < .05$
Green: $p < .01$
Blue: $p < .001$
Black: $p > .05$

IV. Conclusions

In order for HARP to result in significant learning in the areas of intrinsic motivation, valuing science, application knowledge, metacognitive processes, cognitive skills, and content knowledge, curriculum needs to be developed and refined. The particular example of implementation into the general education chemistry class at Taylor University agrees with this as do other implementations in courses at other universities.

A NSF CCLI/TUES grant awarded to Taylor University is focusing on curriculum development with specific guidelines that are being rolled out. The final deliverable will be several curricula developed using HARP that will be available for use in many universities and in many different courses.

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